Wolf Harvest Model Simulation Informational Supplement

Prepared for the FWP Commission, July 2009

Introduction

To explore a variety of potential statewide and individual Wolf Management Unit (WMUs) quotas, FWP developed a mathematical model to simulate wolf harvest. The model is based on data from the 2008 Montana wolf population (birth, death, immigration / emigration as measured by pack formation) and a number of assumptions. The model considers the 2008 wolf population and subjects it to complete matrix of harvest rates for each WMU in all combinations from 5% harvest to 25% harvest. The model was run a second time to subject the wolf population to a complete matrix of harvest rates from 30-70% harvest, again in all combinations across the three WMUs.

After simulating harvest, the model predicts several population parameters at the end of the first calendar year of a hunting season. At the statewide level, the model predicts: 1. total number of wolves (includes a correction factor for 10% lone / missing wolves based on the literature); 2. the number of wolves living in packs (most similar to current, field-based monitoring data); 3. the number of breeding pairs (BPs); and 4. the number of simulations in which the number of BPs or the total wolf population drops below 15 or 100, respectively.

The modeling effort is intended to help determine appropriate harvest levels that would not jeopardize the population or cause it to drop below 15 BPs. Montana is required to maintain at least 10 BPs and 100 wolves as its contribution to a recovered northern Rockies wolf population. However, the U.S. Fish and Wildlife Service would initiate a northern Rockies status review if the Montana (or Idaho) population fell below 15 BPs or 150 wolves for three consecutive years. Neither FWP nor the FWP Commission intend to manage so aggressively as to decrease the wolf population through hunting, agency lethal control (or a combination of the two) down to levels that would jeopardize recovery. Nonetheless, the current model has certain limitations due to its inherent assumptions. Also, it was not constructed in such a way as to predict farther into the future than at the end of the current calendar year. FWP efforts are underway to improve and refine the model that will be applied during the 2010 / 2011 biennial season-setting process that begins December 2009.

At the May 14 (2009) FWP Commission meeting, FWP recommended consideration of a range of statewide quota options from no public harvest (quota of zero) to 207. The Commission adopted a statewide range of 26-165 for public comment. The Commission also requested FWP to compile harvest model simulation results in increments of 25. The model was created to simulate the number of breeding pairs and the total number of wolves at the end of the first year of hunting, using all combinations of different harvest rates in increments of 5%. Potential quota numbers were not the model inputs. Rather, the quota numbers were the outcomes of harvesting a certain percentage of the wolf population. However, we can reverse the process and look for the combination of harvest rates in each of 3 WMUs which will most closely approximate statewide quotas from 26 to 165, in increments of 25.

This document will review the background information about the modeling effort itself. It will supplement all other FWP Wolf Hunting Season and Quota Justification documents, and the Commission and the public are referred back to those documents. Predicted outcomes of statewide quotas of 26, 51, 75. 101, 127, and 165 wolves are presented in narrative format immediately below. Graphical results can be found in the last section.

Summary Results, Narrative

Of the approximate 4,000 combinations of harvest rates from 5% to 70% simulated by the model, most did not result in risky outcomes. At this time, however, FWP and the FWP Commission are only considering conservative quota options from 26-165, which correspond to average harvest rates across all three WMUs from 5% to 30% (Table 1). All of the statewide quota options in this range (26 – 165) are predicted to result in a stable or increasing wolf population at the statewide level. None of the quotas being considered would result in a "risky" outcome in which the number of BPs drops to 15 or fewer (Table 2).

Table 1. Range of harvest rates and corresponding quota levels at the statewide and individual Wolf Management Unit (WMU) level.

TOTAL QUOTA **(mean % harvest rate across all three WMUs)**	**NORTHERN MONTANA** **WMU 1 Quota** **(N. Fork Flathead subunit)**	**WESTERN MONTANA** **WMU 2 Quota**	**SOUTHWESTERN MONTANA** **WMU 3 Quota**
26 (5%)	14 (2 subquota)	6	6
51 (10%)	28 (2 subquota)	11	12
75 (15%)	41 (2 subquota)	22	12
101 (20%)	55 (2 subquota)	28	18
127 (25%)	69 (2 subquota)	28	30
165 (30%)	86 (2 subquota)	50	29

Table 2. Post-season statewide wolf population information predicted by the harvest simulation model, at the end of calendar year of the first hunting season. The biological baseline of the model is the 2008 wolf population (Sime et al. 2009).

TOTAL QUOTA **(mean % harvest rate across all three WMUs)**	**Predicted Total Population**	**Predicted Total Number of Wolves Living in Packs**	**Predicted Number of Breeding Pairs**
26 (5%)	704	634	58
51 (10%)	679	611	56
75 (15%)	655	590	52
101 (20%)	629	566	50
127 (25%)	603	543	48
165 (30%)	595	535	45

Background Details, The Harvest Simulation Model

FWP explored the potential outcomes of a quota-based wolf hunting season by simulating various harvest rates in each of three wolf management units. The simulations were intended to gauge the response of Montana wolves to harvest in the year immediately following implementation and do not reflect an approach to long-term sustainability of wolf harvest. A four -step process was used.

The primary goals were to:

- Examine various combinations of harvest rates to determine population sensitivity by adding harvest mortality to existing causes of death for each of the three management units and statewide, given the 2007 – 2008 population data.
- Gauge the risk of the statewide number of BPs (the federal recovery definition) dropping below 15 in the year following the first year of hunting implementation.
- Consider various combinations of harvest rates that result in a predicted wolf population increase, population stability, or a population decrease one year later.
- Predict the number wolf packs, the number of BPs, and the total number of wolves statewide in the first year following harvest.

1. Determine Population Baselines

The Montana wolf population has increased from a minimum of 66 wolves (6 BPs) in 1995 to approximately 497 wolves (34 BPs) as of December 31, 2008. But in order to simulate the effects of harvest, a general baseline understanding of wolf population dynamics is the required first step. Therefore, a population model was created and was largely based on the biological features of wolves in each of the three management units (Mitchell et al. 2008). The model incorporated birth, death, immigration, and emigration for each unit using actual data from 2007 and 2008. Several assumptions were necessary. Each assumption is likely to be violated to one degree or another, but this uncertainty can't be easily quantified. Nonetheless, calculation and consideration of confidence limits is one way to begin accounting for uncertainty. The assumptions were:

- Rates of birth, death, immigration, and emigration are known with certainty, constant and equal to those observed in each area in the previous year.
- Mortality rates are constant for individual wolves.
- Immigration results in the formation of new packs of a consistent age structure and at a constant rate within each area.
- Reproduction results in a consistent number of pups and only in packs that existed in the previous year in each area.
- About 10% of the wolf population is comprised of single wolves not associated with a pack – thus the minimum known population of "pack-living" wolves was increased by 10% in each area. The percentage is based on the published literature since FWP does not have an accurate way to estimate the number of lone / dispersing wolves.

2. Simulate Effects of Harvest

Once the basic wolf population dynamics are determined and predicted, FWP then simulated how harvest might affect the number of wolves, number of packs, and the number of BPs in the first year following harvest.

Quotas were set as percentages of the previous year's minimum known wolf population in each area. Thus, reproduction, immigration / emigration, and mortality in the year of harvest are not considered in the simulation exercise itself but will be at the time quotas/ permit levels are set and finalized. This allows FWP to be more conservative when recommending tentative quotas in May of the year of harvest. Final quotas would be established in July immediately prior to a season which starts in mid-

September in a limited number of areas. This allows current year's data to be incorporated in case there are significant, unexpected developments such poor pup survival due to disease or increased mortality due to conflicts with livestock. See Figure 1.

Harvest quotas ranging from 5% to 70% of the population in each area were simulated. The simulation included all possible combinations of these rates at 5% increments for a total of about 4000 combinations. Each combination of harvest rates was simulated 1000 times. The number of wolves, wolf packs, and BPs after one harvest season were estimated after each simulation run.

The harvest simulations made the simplifying assumptions that:

- Wolf mortality due to public harvest is random and is additive to wolf dispersal and all other forms of mortality, including natural mortality, illegal wolf harvest, and mortality due to depredation in each area.
- Managers do not know the statewide number of BPs with 100% certainty; therefore the BP probability estimator was used to estimate the number of BPs for those packs lacking field observations to confirm BP status (Mitchell et al. 2008, Gude et al. *in review*). This approach generates an estimate of the number of BPs in Montana, as well as lower and upper confidence limits that reflect the uncertainty involved in estimation (i.e., we are 95% certain that the true number of BPs falls between the upper and lower confidence limits (Figure 2).
- Managers do not know the number of lone or dispersing wolves with certainty. Therefore, the model input consists of wolves known to be living in packs according to FWP's field monitoring efforts. The number of lone / dispersing wolves is accounted for mathematically. According to the published literature, an estimated 10-15% of the wolf population occurs as lone individuals. Thus the total number of "pack-living" wolves predicted by the model needed to be adjusted upward by 10% to arrive at the predicted total wolf population.

3. Simulation Results

The results of each combination of harvest rates were scrutinized to determine whether it resulted in a "risky" outcome in which the lowest possible number of BPs within the 95% confidence limit went below 15. This threshold represents a boundary below which a harvest season in the following year would be cancelled, as dictated by the state management plan. By accounting for uncertainty through confidence limits, assuming that harvest would be additive to all other forms of mortality, and only considering "no risk" harvest scenarios, FWP is taking a conservative approach.

The simulations indicated that the Montana wolf population can support a harvest season in various combinations of rates in each of the three WMUs and remain stable to increasing for one year, given the population vital rates observed in 2007 and 2008. Generally speaking, progressively higher harvest rates resulted in progressively steeper population declines, although the relationship was not linear. This is because of baseline population differences between each of the three units (Mitchell et al. 2008) and other types and levels of wolf mortality. The Northern Montana Wolf Management Unit (#1) is the most sensitive area for the random harvest of wolves if the goal is to maintain at least 15 BPs in the state.

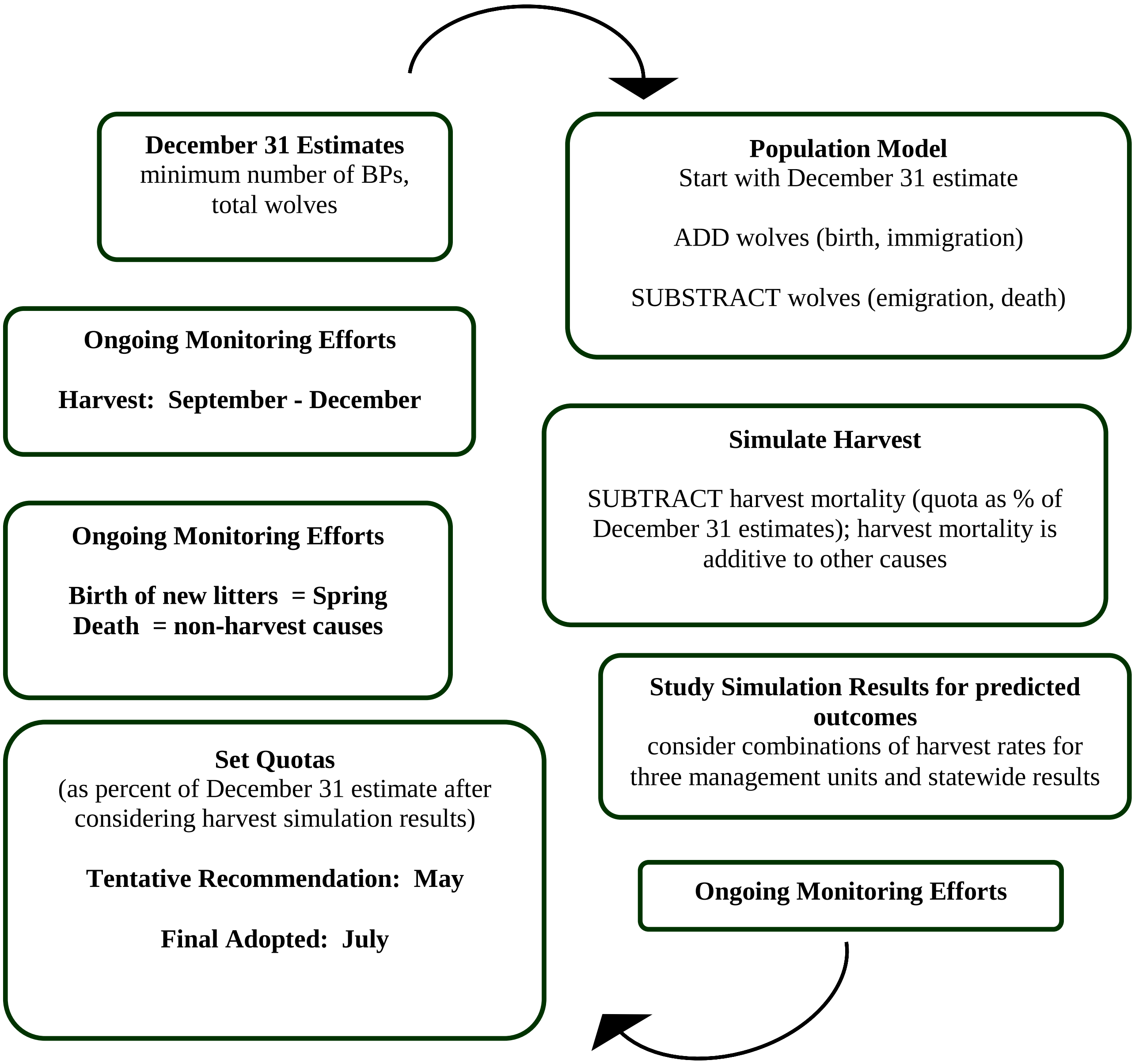

Figure 1. A flow chart of wolf harvest simulation model and quota setting process.

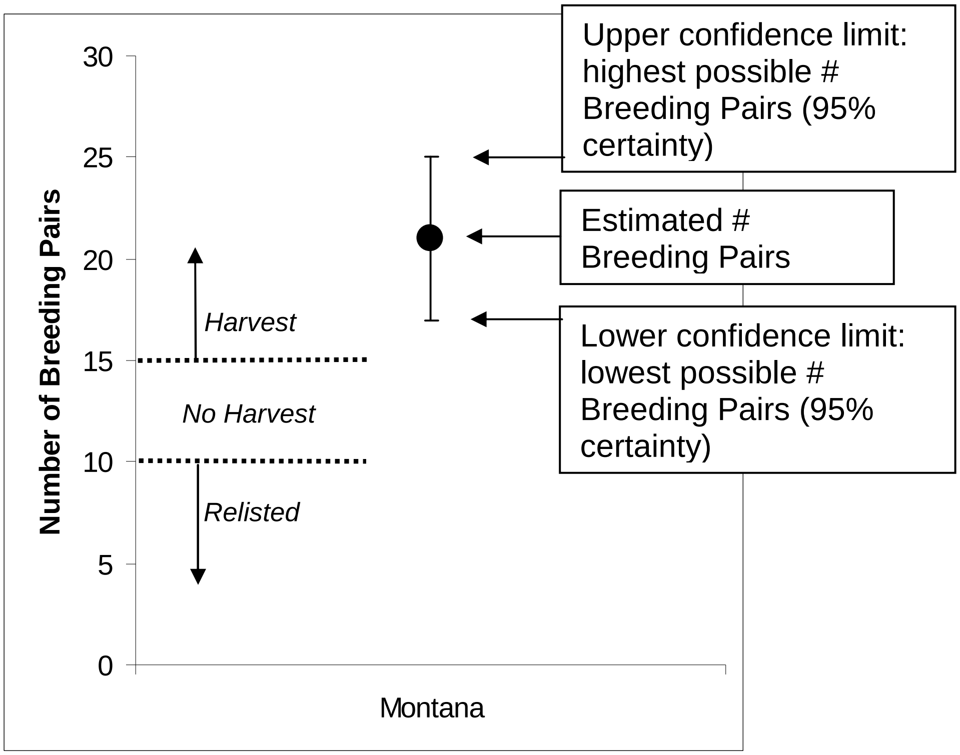

Figure 2. Example of hypothetical predicted number of Breeding Pairs for Montana, with upper and lower confidence limits.

4. Consider Combinations of Harvest Rates

Based on the 2007-2008 population model, nearly all combinations of harvest rates resulted in a “no risk” outcome where the 95% lower confidence limit for the BP estimate did not drop below 15. Wolf population dynamics and current levels of human-caused mortality are different in each of the three management units (Mitchell et al. 2008). Therefore, various combinations of harvest rates yielded similar predicted statewide outcomes. However, these results suggested that harvest rates could vary within each of the proposed management units to reflect local social and biological factors such as the status of wolf and/or prey populations, livestock damage, social tolerance, etc. while still maintaining a secure population statewide and assuring connectivity within Montana and the northern Rockies wolf populations, respectively.

Quota percentages were based on the minimum number of wolves that FWP knew were present on December 31 of the previous year. There will likely be more wolves present at the start of the current year’s hunting/trapping season due to the current year’s reproduction and immigration adding to the population. Current year’s mortality could be accounted for at the time final quotas are set. Increasing population trends to date demonstrate that reproduction and immigration have exceeded emigration and total mortality. In this way, the model and quota-setting process is conservative -- it is based on known wolves plus an estimated 10% lone wolves not affiliated with a pack and can account for wolf mortality (and reproduction to some extent) through July when final quotas are set.

There is considerable variation in the level of human-caused mortality that a wolf population can withstand and remain relatively stable. Some studies are beginning to address the question about the potential that regulated public harvest mortality can compensate for other forms of mortality. General rules of thumb are available in the published literature. Important factors include overall wolf density and population size, reproduction, immigration / emigration rates in the local Montana and regional northern Rockies population, road density, habitat, and other sources and levels of mortality (e.g. livestock-related), prey base, and livestock density (Fuller et al. 2003; Person and Russell 2007; Adams et al. 2008).

Depending on the desired goal or outcome one year later, various combinations of harvest rates could be selected to facilitate a population increase, population stability, or a population decrease. The following bar graphs illustrate the predicted outcomes of various combinations of harvest rates in each of the three areas one year immediately following harvest. All results presented are based on current levels of field monitoring effort.

References

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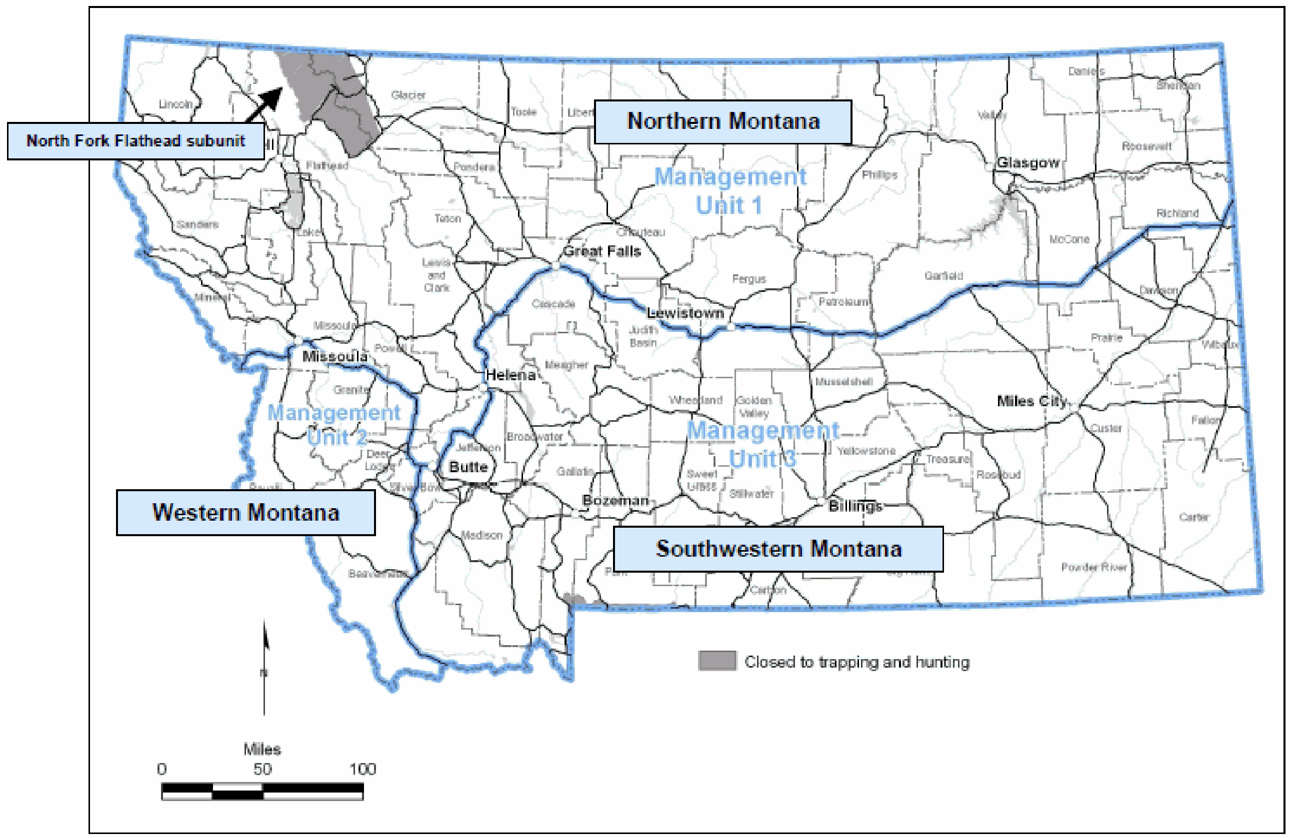

Figure 3. Three Wolf Management Units, and the North Fork Flathead Subunit.

Graphical Results of Statewide Quotas from 25-165, in Increments of 25

The following bar graphs illustrate a variety of scenarios of various harvest rates in each of the three proposed WMUS (see Figure 3). The graphs illustrate the expected statewide number of BPs, the percent of the simulations that resulted in a "risky" outcome (defined as the 95% lower confidence limit dropping below 15 BP), the number of wolves living in packs, and the expected number of packs one year after implementation. All scenarios presented represent conservative approaches to the first wolf hunting season.

Statewide Harvest Quota of 26, Figure 4

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 14, N. Fork Flathead subunit subquota = 2; WMU 2 = 6; WMU 3 = 6

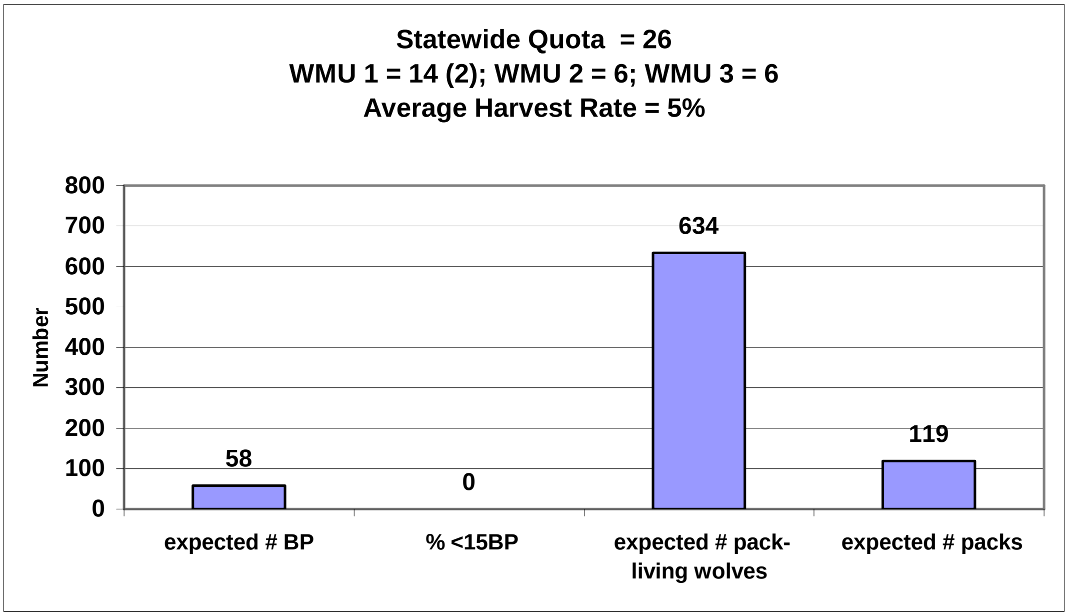

Figure 4. The model predicted 634 total wolves in established packs and a total of 58 BPs. After accounting for lone wolves, the model predicted a total population of 704 wolves.

Statewide Harvest Quota of 51, Figure 5

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 28, N. Fork Flathead subunit subquota = 2; WMU 2 = 11; WMU 3 = 12

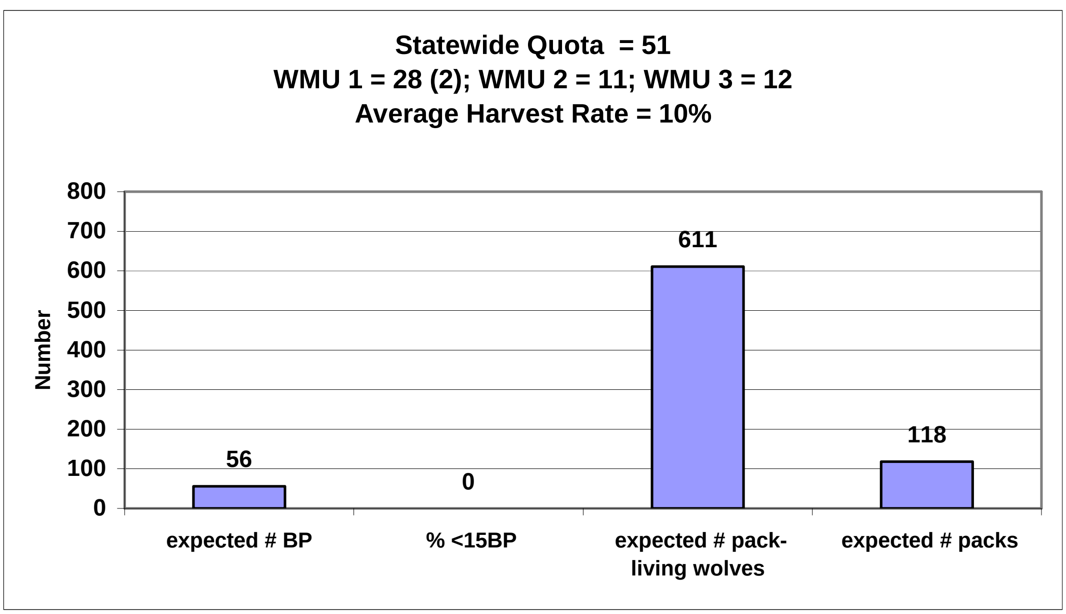

Figure 5. The model predicted 611 total wolves in established packs and a total of 56 BPs. After accounting for lone wolves, the model predicted a total of population of 679 wolves.

Statewide Harvest Quota of 75, Figure 6

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 41, N. Fork Flathead subunit subquota = 2; WMU 2 = 22; WMU 3 = 12

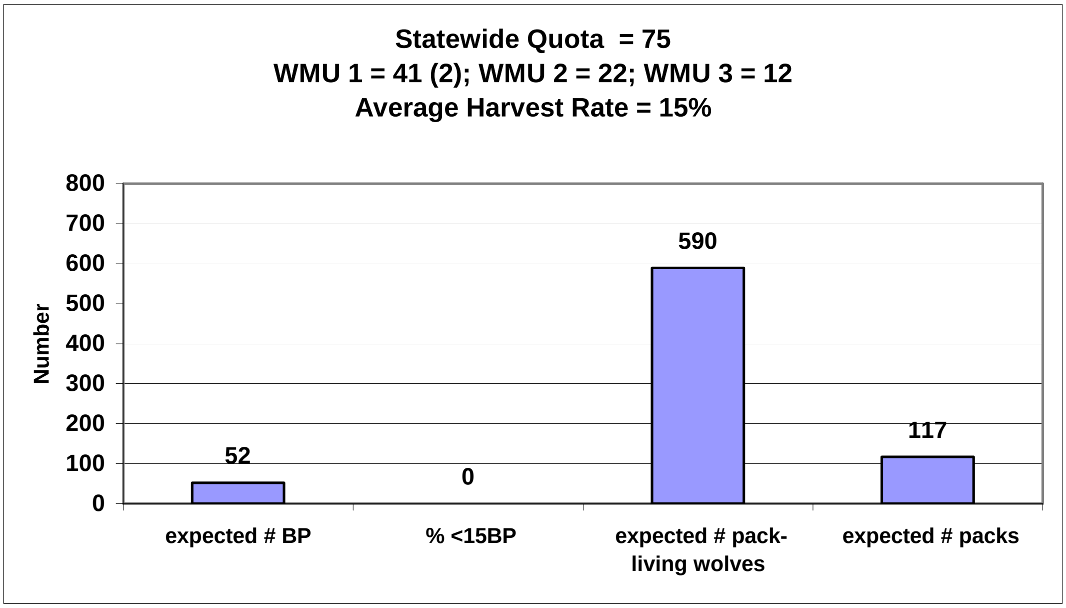

Figure 6. The model predicted 590 total wolves in established packs and a total of 52 BPs. After accounting for lone wolves, the model predicted a total of population of 655 wolves.

Statewide Harvest Quota of 101, Figure 7

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 55, N. Fork Flathead subunit subquota = 2; WMU 2 = 28; WMU 3 = 18

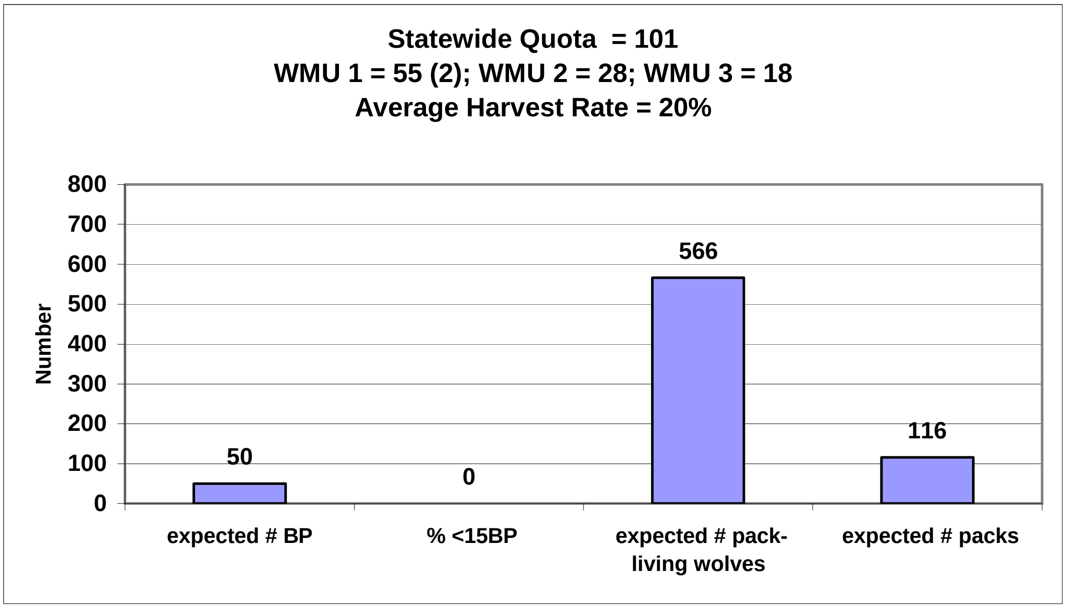

Figure 7. The model predicted 566 total wolves in established packs and a total of 50 BPs. After accounting for lone wolves, the model predicted a total of population of 629 wolves.

Statewide Harvest Quota of 127, Figure 8

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 69, N. Fork Flathead subunit subquota = 2; WMU 2 = 28; WMU 3 = 30

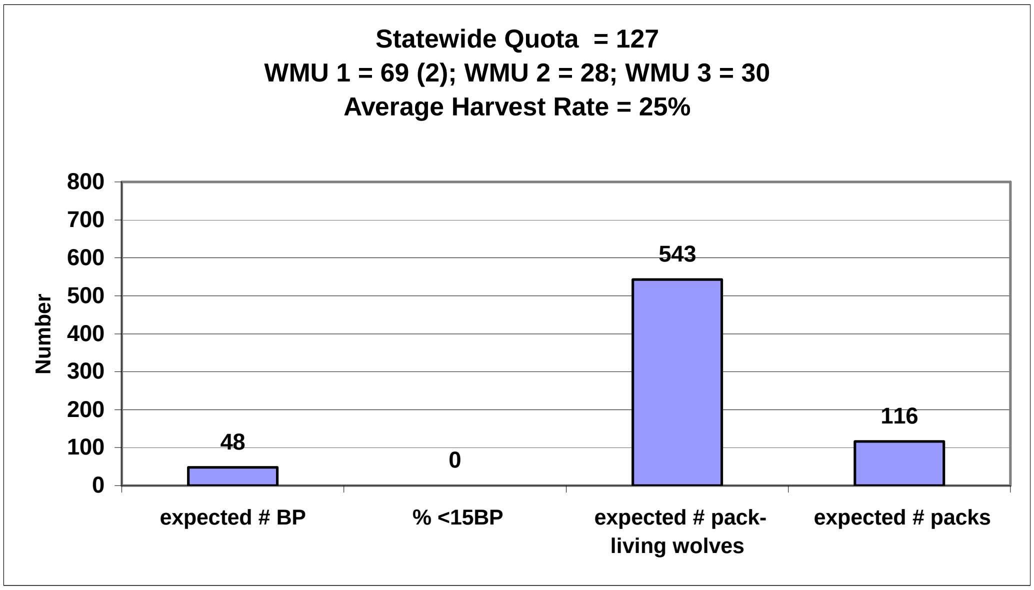

Figure 8. The model predicted 543 total wolves in established packs and a total of 48 BPs. After accounting for lone wolves, the model predicted a total of population of 603 wolves.

Statewide Harvest Quota of 165, Figure 9

- Low harvest rates in each WMU; no risk of the lower confidence limit dropping below 15 BP
- Monitoring at current levels of effort
- Quotas: WMU 1 = 86, N. Fork Flathead subunit subquota = 2; WMU 2 = 50; WMU 3 = 29

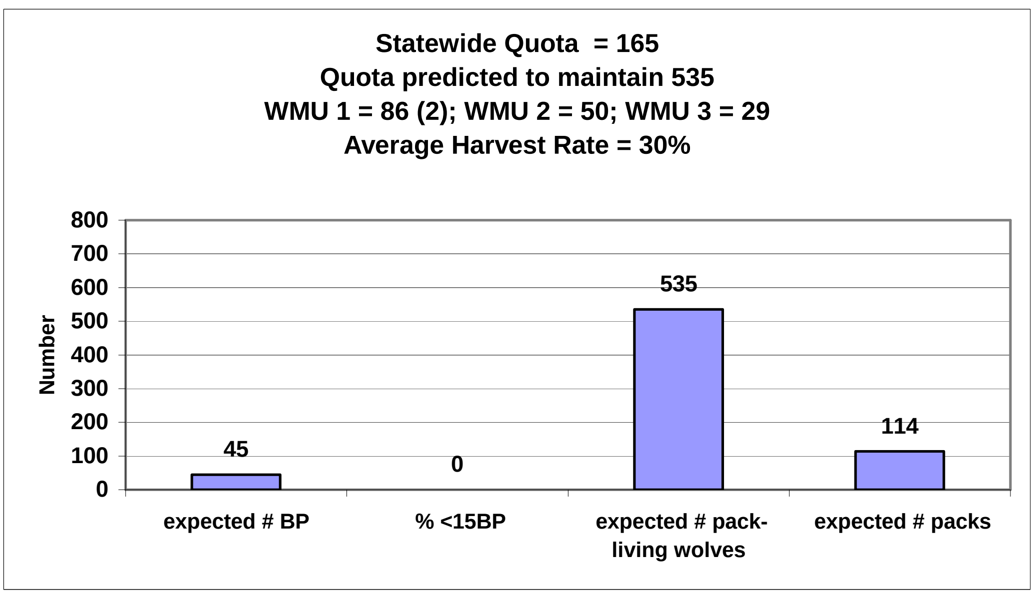

Figure 9. The model predicted 535 total wolves in established packs and a total of 45 BPs. After accounting for lone wolves, the model predicted a total of population of 595 wolves.

Document Prepared by: Carolyn Sime. Harvest simulation model process completed by Justin Gude, Robin Russell, C. Sime, FWP; Dr. Michel Mitchell and David Ausband, University of Montana Cooperative Wildlife Research Unit; 6-19-09